Aquatic Life Impairment in the Occoquan Reservoir

First Technical Advisory Committee Meeting
August 30th 2006

DEQ Northern Virginia Regional Office
Woodbridge, Virginia

Photo: DCR

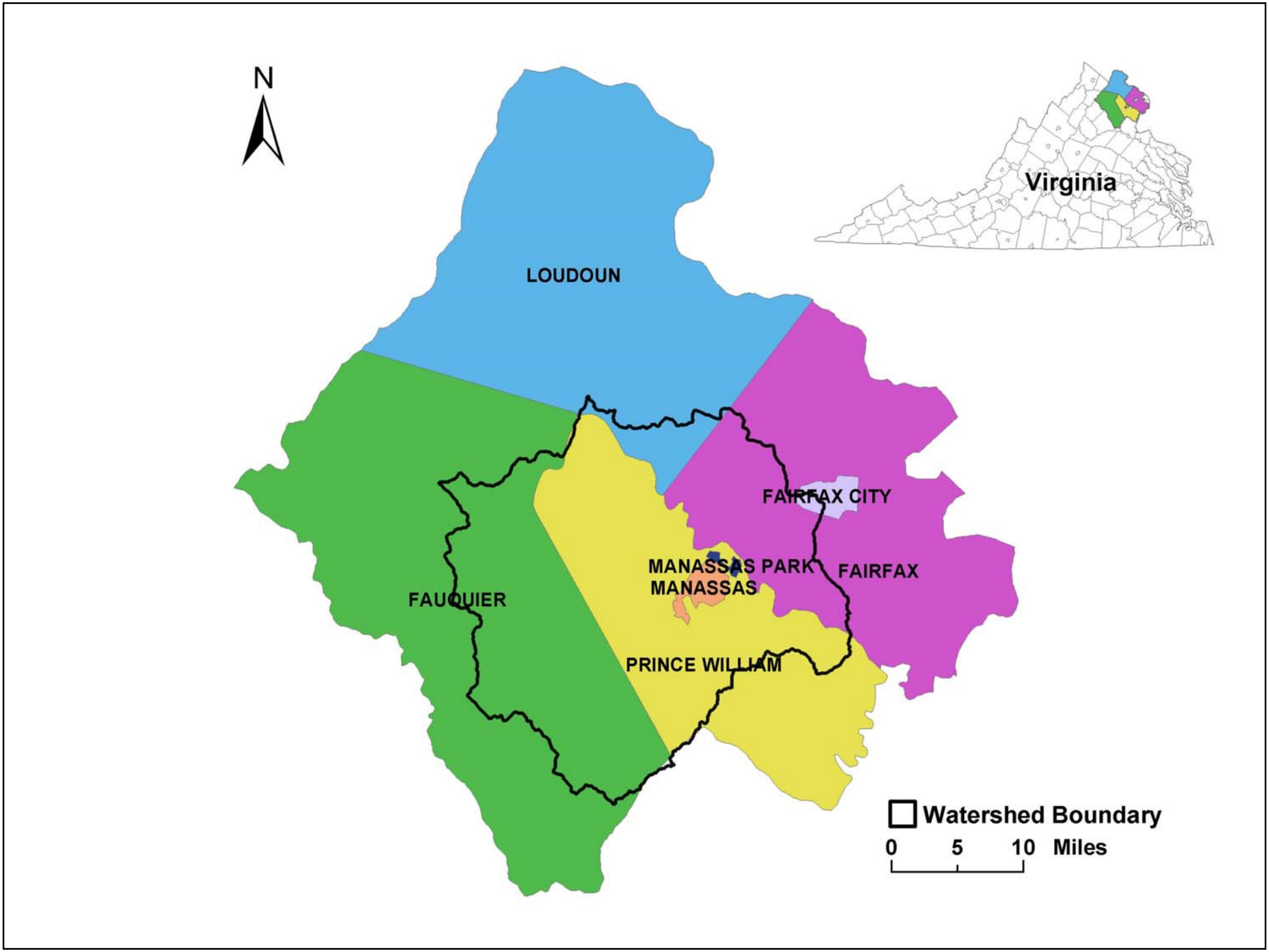
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

Impairment in the Occoquan Reservoir

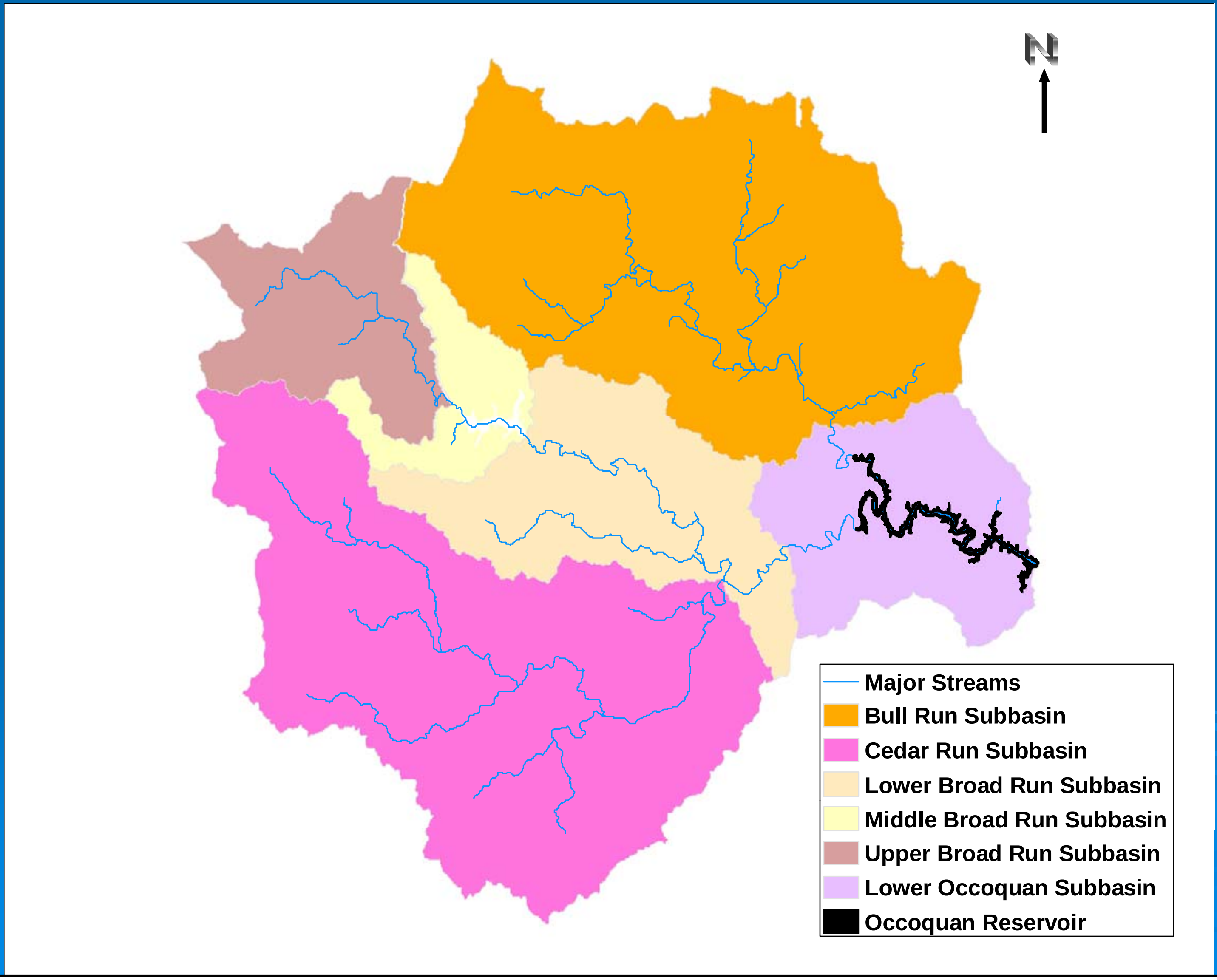
- DO impairment

Note: The impairment is for the aquatic life use criteria and not for use as a public water supply.

Photo: OWML


N
Virginia
LOUDOUN
FAIRFAX CITY
MANASSAS PARK
FAIRFAX
MANASSAS
FAUQUIER
PRINCE WILLIAM
Watershed Boundary
0 5 10 Miles

Area of Study



Sampling Stations in the Occoquan Reservoir

Data from the four stations

- All the four stations (RE02, RE15, RE30, RE35) reported excursions from the minimum dissolved oxygen criteria of 4 mg/L.
- Greater than 10% of the samples exceeded the criterion in both surface and bottom waters at station RE02.
- Greater than 10% of the samples exceeded the criterion in the bottom waters only at stations RE15, RE30 and RE35.
- The phosphorous threshold screening value of 50 µg/L for fresh water lakes was exceeded in greater than 10% of samples in both the surface and bottom waters.

Reasons for DO Impairment

The source of impairment is listed as ‘Natural/Stratification’.

The main reasons stated for the impairment are as below:

- Bottom dissolved oxygen depletion occurs naturally in reservoirs due to stratification.
- Poor mixing of the water column at station RE02.
- Nutrient loading (phosphorous) from the watershed.
- Historical nutrient input.

Modeling the System

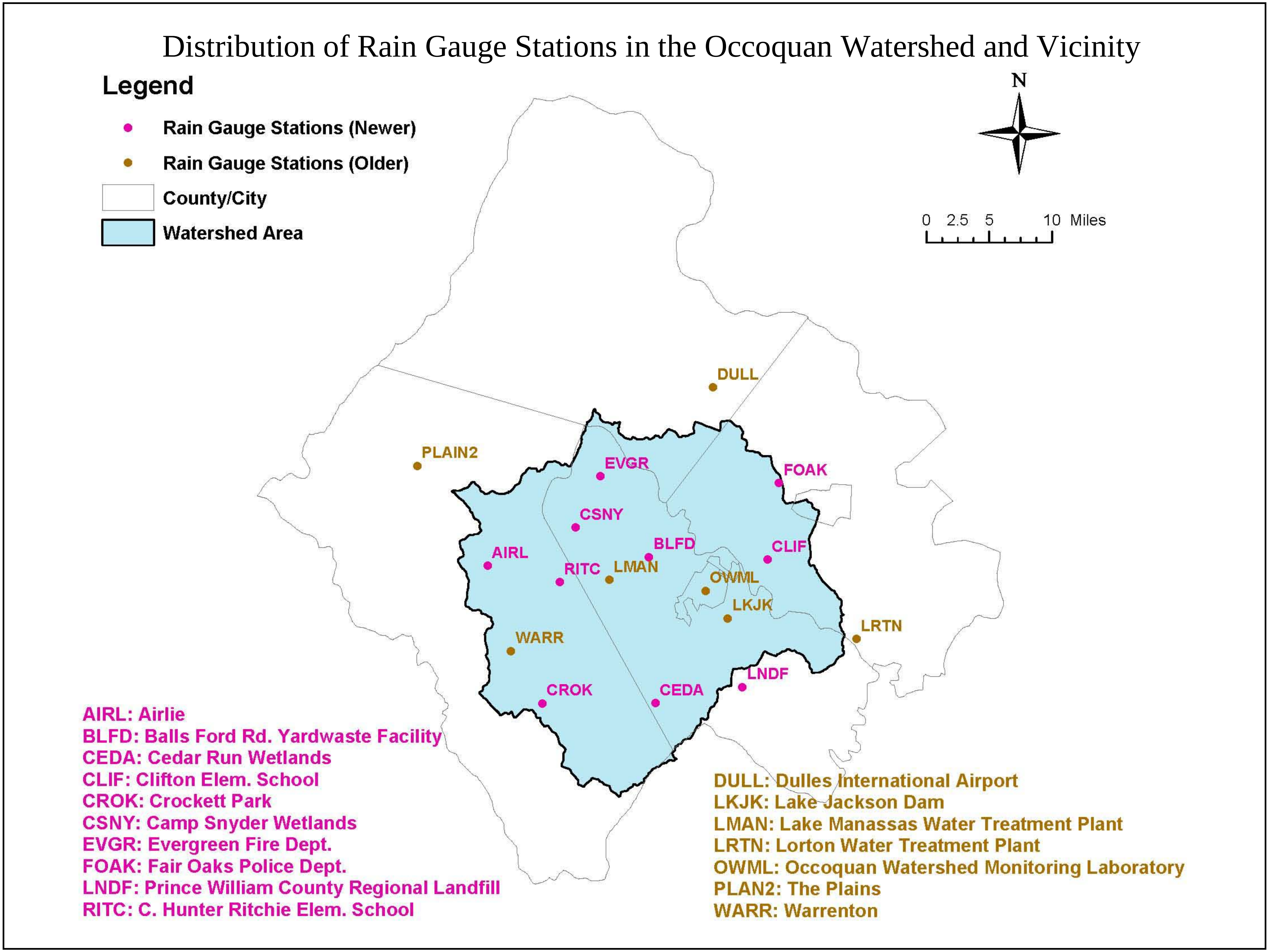
- For simulating overland surface runoff and flow in streams, a model that accounts for surface and groundwater flows, and responds to meteorological input, is required.
- Because of the complexity of water flow in reservoirs and lakes, and because stratification must be simulated, a hydrodynamic model must be used.
- Both types of models are incorporated in the Occoquan Model.

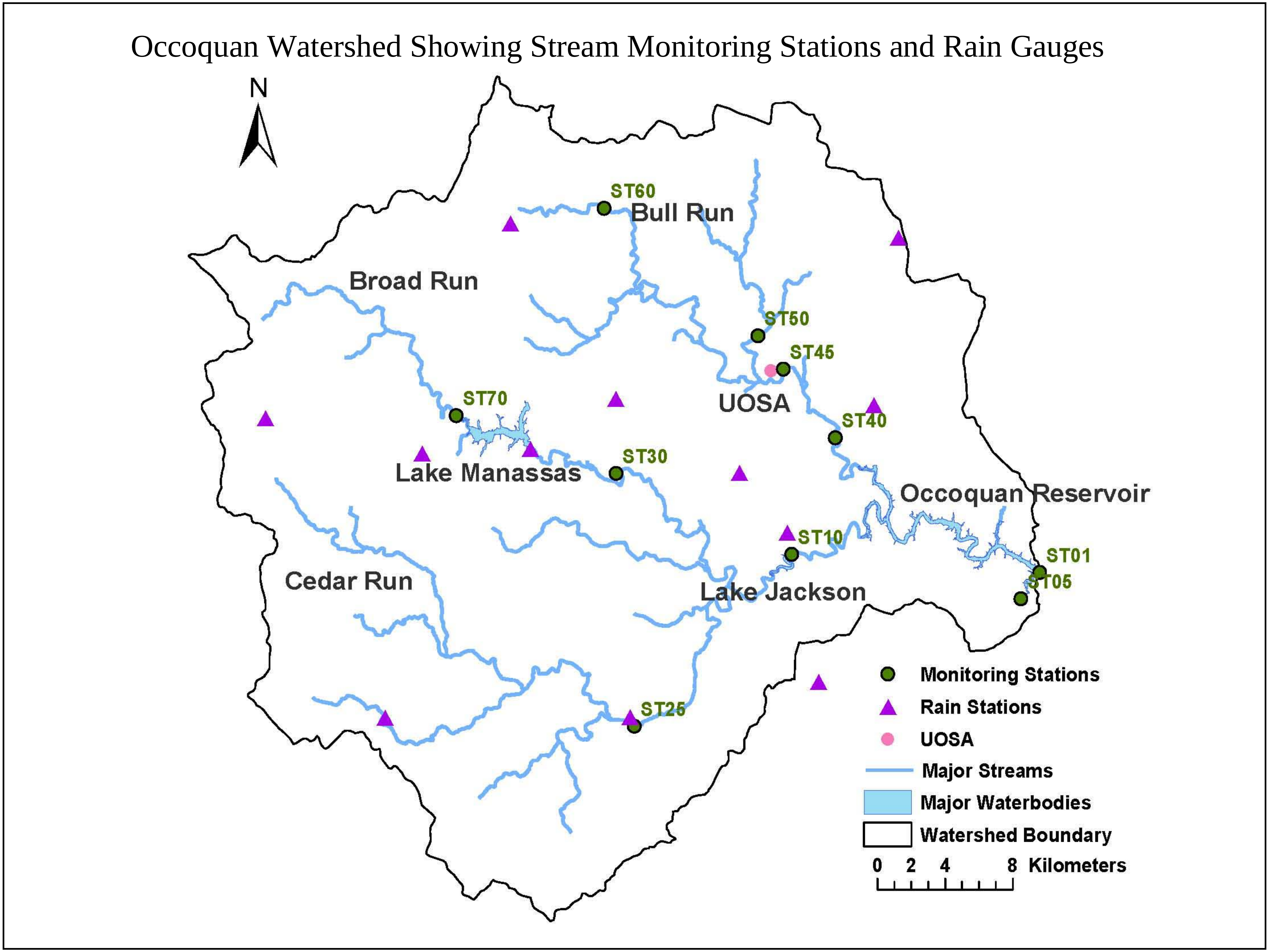
The Occoquan Model - I

- The Model has a continuous development-and-update cycle, with refinements added with each update.
- The work is overseen by a modeling subcommittee.
- Uses two software model packages to simulate the entire Occoquan Watershed.
- HSPF (Hydrologic Simulation Procedure – Fortran) is used to simulate runoff and resultant water flow in streams.
- CE-QUAL-W2 (an Army Corps of Engineers 2-D water quality model) is used to simulate hydrodynamics and water quality in the reservoirs.

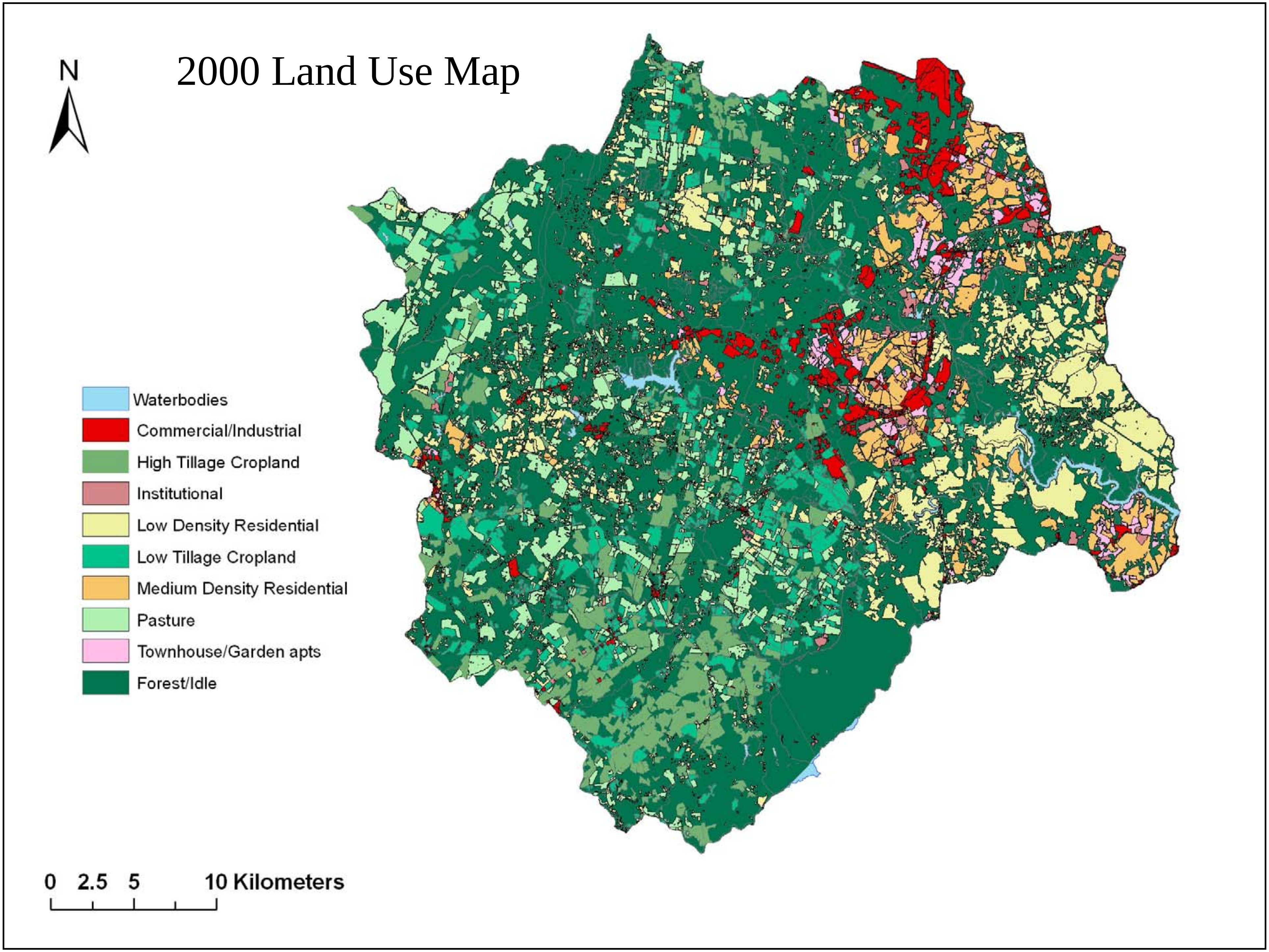
The Occoquan Model - II

- The entire model uses 6 applications (submodels) of HSPF and 2 applications of CE-QUAL-W2 (also called W2), linked in a complex way.
- Much of the data (flow, meteorological and water quality) are derived from the monitoring database generated by the Occoquan Laboratory over the course of almost 35 years.
- Land use data are provided by the Northern Virginia Regional Commission. The Model uses 5-year periods for each update, as this is the cycle on which landuse information is updated.


Distribution of Rain Gauge Stations in the Occoquan Watershed and Vicinity
Legend
Rain Gauge Stations (Newer)
Rain Gauge Stations (Older)
County/City
Watershed Area
N
0 2.5 5 10 Miles
DULL
PLAIN2
EVGR
FOAK
CSNY
BLFD
AIRL
CLIF
RITC
LMAN
OWML
LKJK
LRTN
WARR
LNDF
CROK
CEDA
AIRL: Airlie
BLFD: Balls Ford Rd. Yardwaste Facility
CEDA: Cedar Run Wetlands
CLIF: Clifton Elem. School
CROK: Crockett Park
CSNY: Camp Snyder Wetlands
EVGR: Evergreen Fire Dept.
FOAK: Fair Oaks Police Dept.
LNDF: Prince William County Regional Landfill
RITC: C. Hunter Ritchie Elem. School
DULL: Dulles International Airport
LKJK: Lake Jackson Dam
LMAN: Lake Manassas Water Treatment Plant
LRTN: Lorton Water Treatment Plant
OWML: Occoquan Watershed Monitoring Laboratory
PLAN2: The Plains
WARR: Warrenton



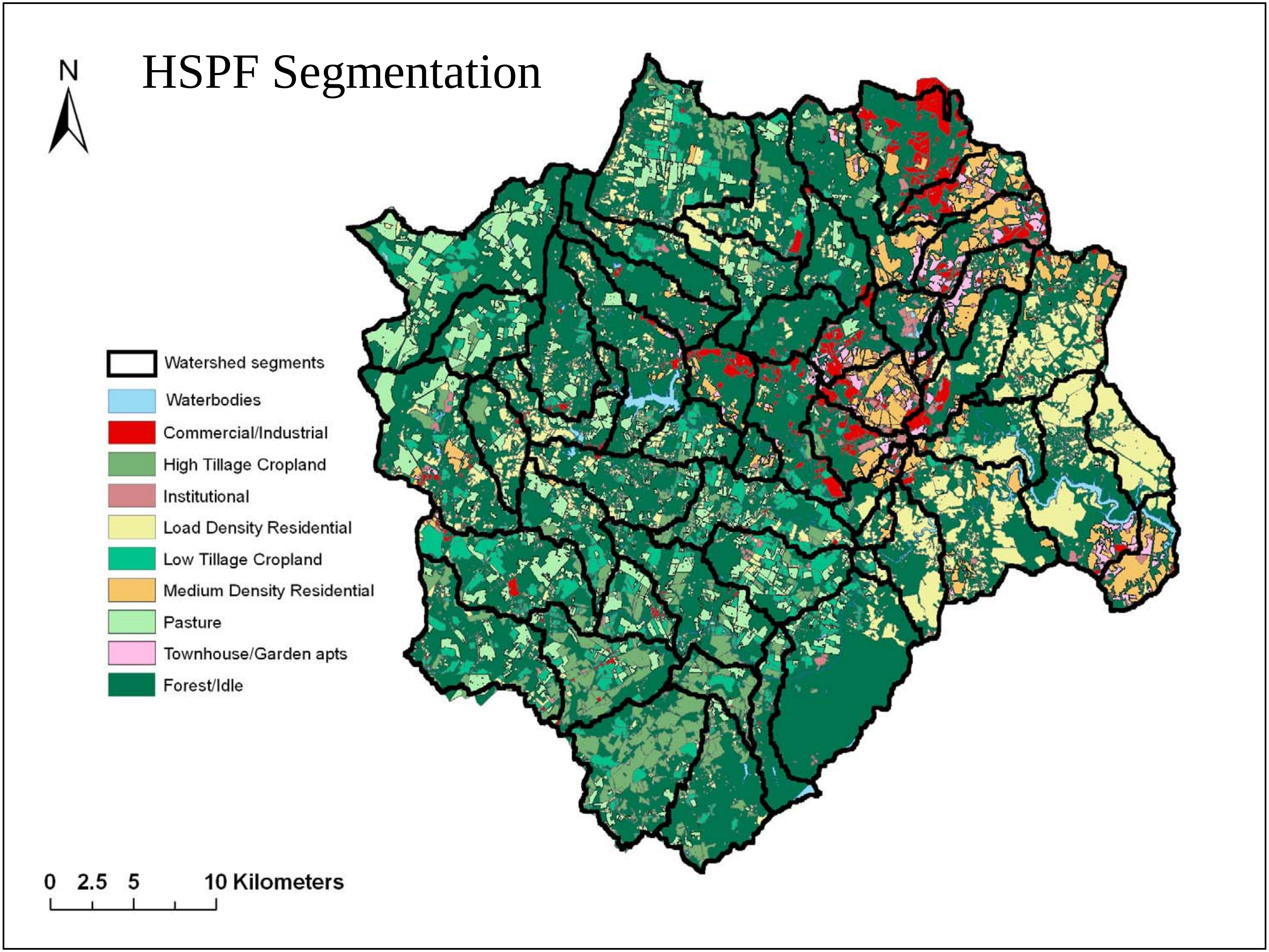
Occoquan Watershed Showing Stream Monitoring Stations and Rain Gauges
N
ST60
Bull Run
Broad Run
ST50
ST45
UOSA
ST70
ST40
ST30
Lake Manassas
Occoquan Reservoir
ST10
ST01
ST05
Cedar Run
Lake Jackson
ST25
Monitoring Stations
Rain Stations
UOSA
Major Streams
Major Waterbodies
Watershed Boundary
0 2 4 8 Kilometers


2000 Land Use Map
N
Waterbodies
Commercial/Industrial
High Tillage Cropland
Institutional
Low Density Residential
Low Tillage Cropland
Medium Density Residential
Pasture
Townhouse/Garden apts
Forest/Idle
0 2.5 5 10 Kilometers

Consolidation of Land Use Categories

Land Use Categories in Map	Characteristics	Land Use Categories in Model Applications
Estate	Estate Single Family Housing (0.05-0.2 DU*/acre)	Low Density Residential
Low Density Residential	Large-Lot Single Family Housing (0.5-2.0 DU/acre)	
Medium Density Residential	Medium Density Single Family Housing (3-6 DU/acre)	Medium Density Residential
Townhouse/Garden Apartment	Multi-Family Housing (>6 DU/Acre)	Townhouse/Garden Apartment
Industrial		Industrial/Commercial
Commercial		
Institutional		Institutional
Forest/Idle		Forest/Idle
Golf	Golf Courses	
Livestock/Pasture		Pasture
Conventional Tillage Grain		High Tillage Cropland
Mix Conventional Tillage Grain		
Min. Tillage Grain		Low Tillage Cropland
Mixed Min. Tillage		

*DU: Dwelling Units


HSPF Segmentation
N
Watershed segments
Waterbodies
Commercial/Industrial
High Tillage Cropland
Institutional
Load Density Residential
Low Tillage Cropland
Medium Density Residential
Pasture
Townhouse/Garden apts
Forest/Idle
0 2.5 5 10 Kilometers

Permitted Point Source Discharges in the Occoquan Watershed

1. UOSA (14631 Compton Road):
   Cub Run – 64 MGD
2. Vint Hill Station WWTP (Vint Hill Farms Station):
   South Run/Kettle Run – 0.95 MGD
3. Camp Upshur STP (MCB-Quantico):
   Cedar Run, Unnamed Tributary – 0. 04 MGD
4. Town and County Restaurant (5037 Lee Highway, New Baltimore):
   Broad Run , Unnamed Tributary – 0.015 MGD
5. Cecil's Service & Equipment, Inc. (5021 Lee Highway, off State Route 29 North, 0.5 miles north of intersection of Rt. 29 and Rt. 60):
   Broad Run – 0.01 MGD
6. H.M. Pearson Elementary School STP (9347 Bastable Mill Road, Catlett) :
   Cedar Run – 0.0079 MGD
7. Evergreen Country Club (15900 Berkley Drive, Haymarket):
   Chestnut Lick, Unnamed Tributary – 0.0075 MGD
8. Smith-Midland Corporation (5119 Catlett Road, Midland):
   Licking Run – 0.003 MGD

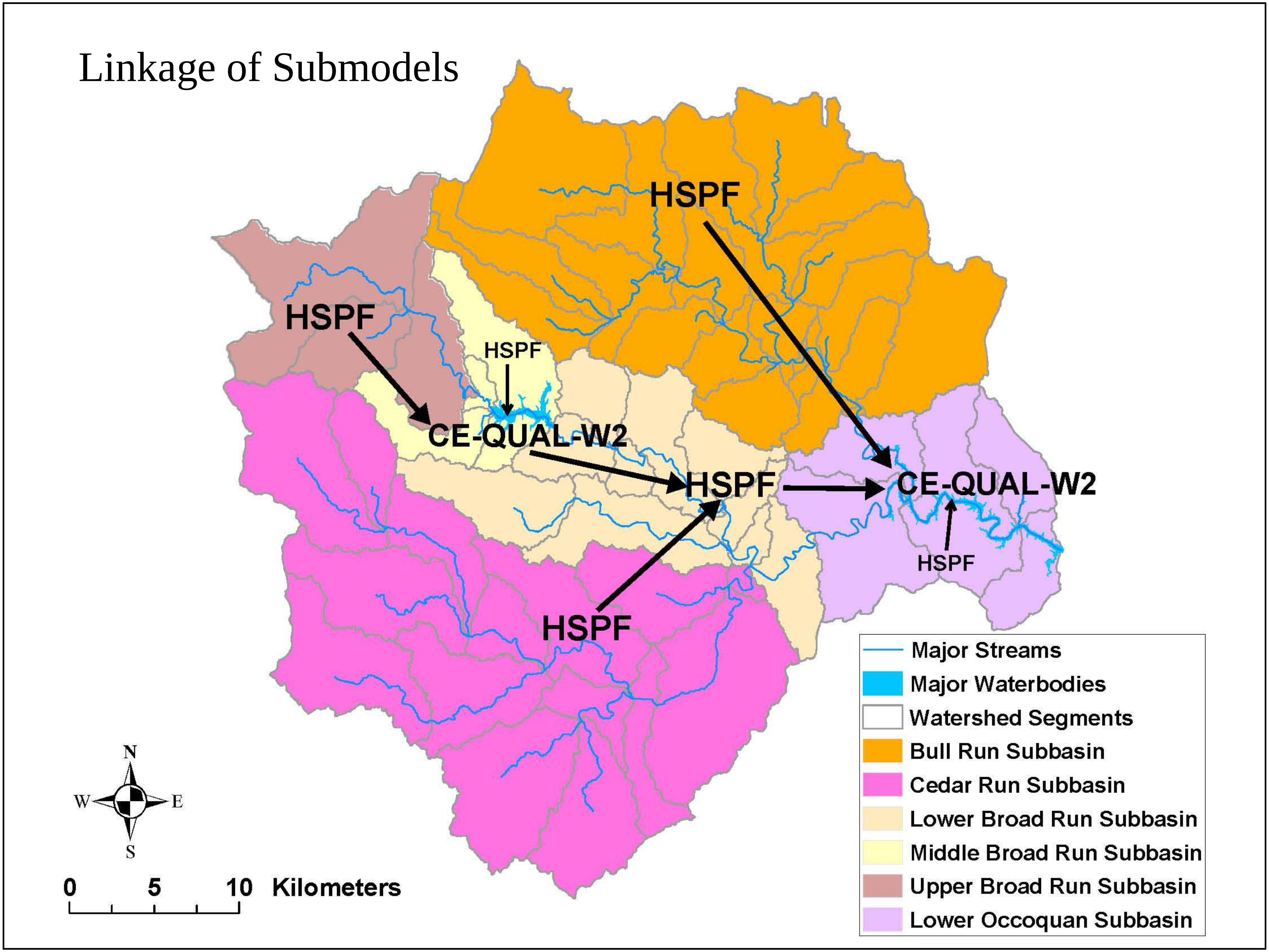
Total of all permitted point source discharges : 65.0334 MGD

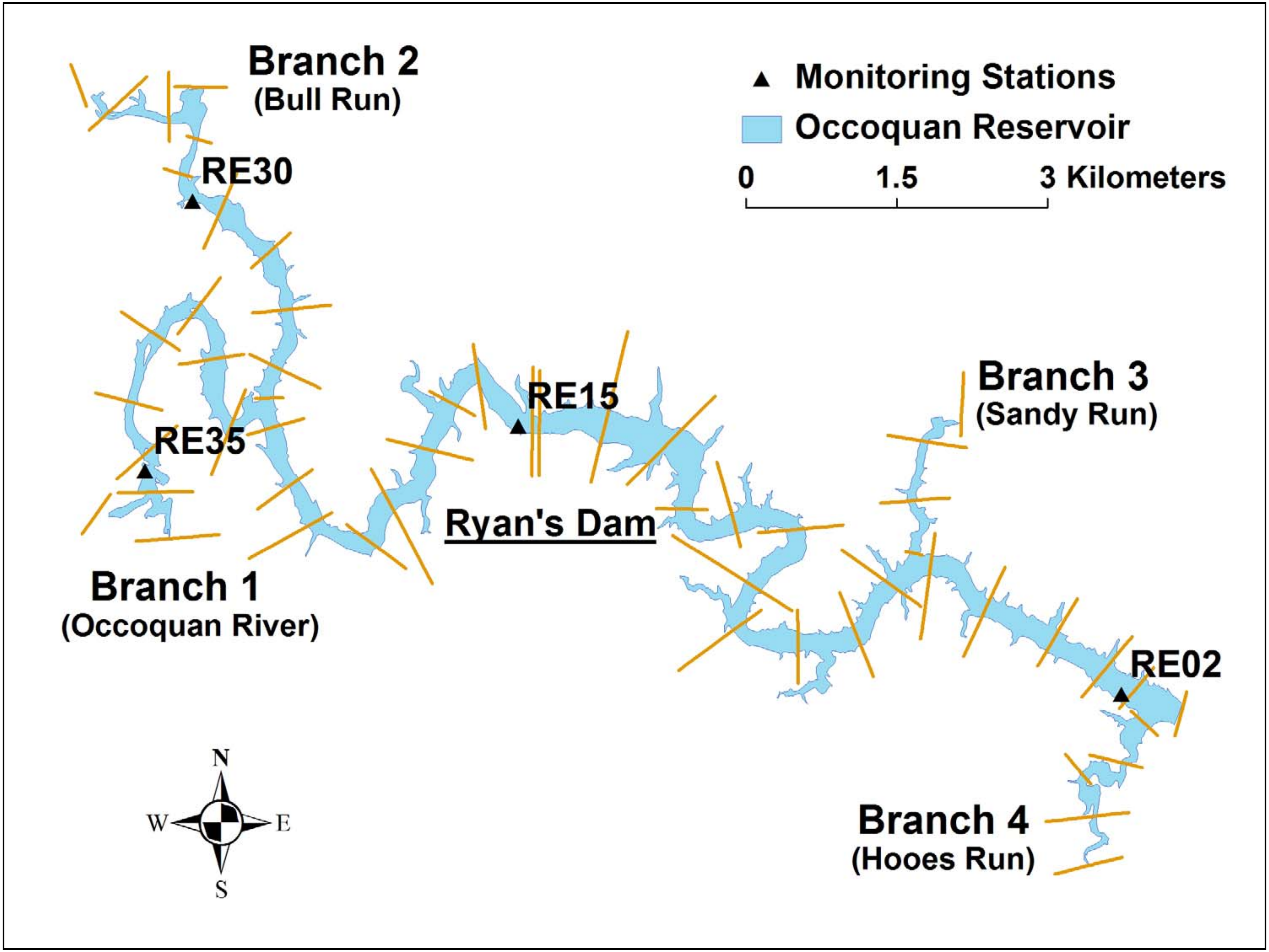
Permitted General Discharges in the Occoquan Watershed

Number of permitted general discharges:	159
Allowed maximum discharge for each permit:	0.001 MGD
Total maximum flow for general discharges:	0.159 MGD

Point Sources

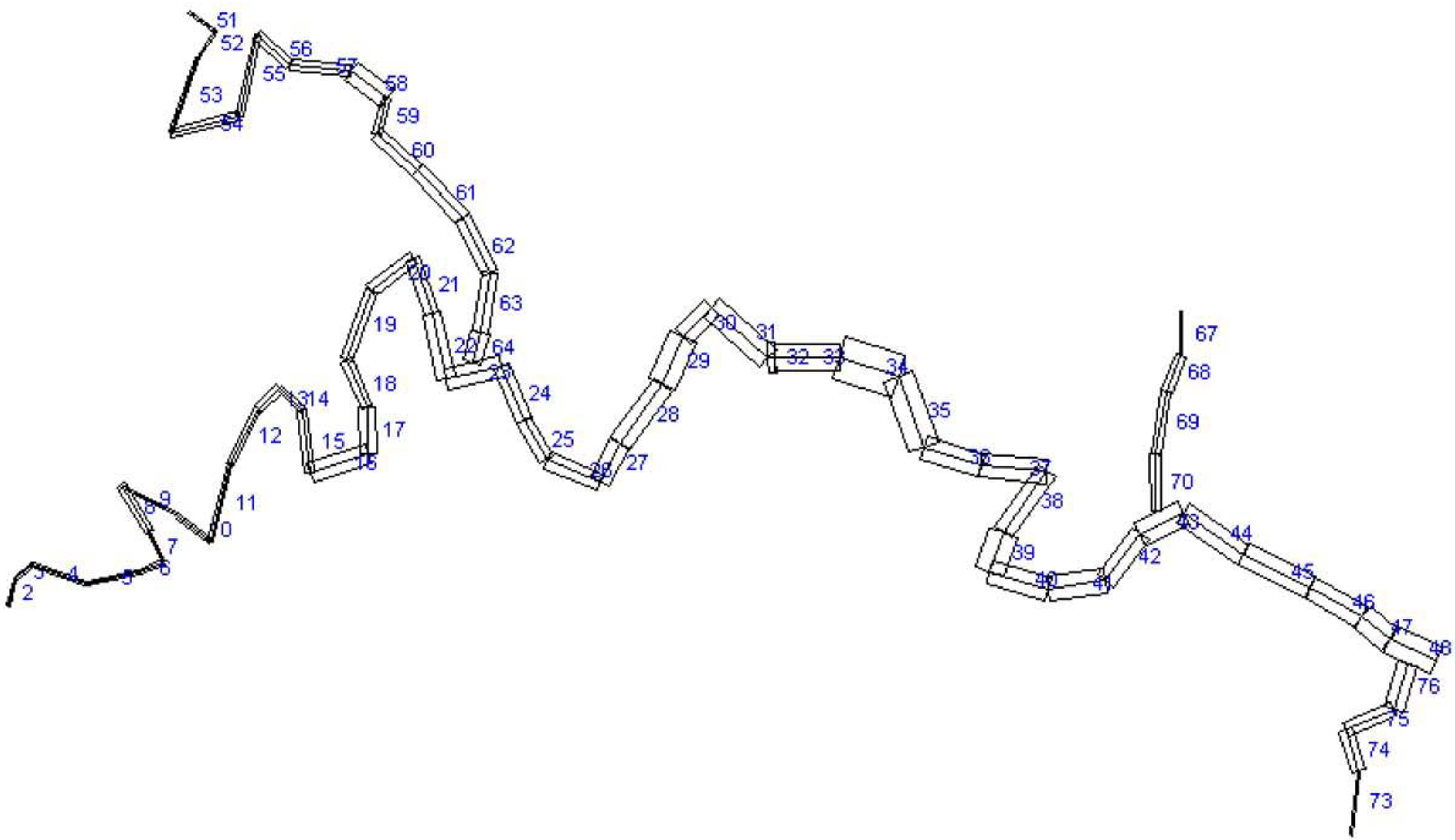
- Total flow contribution from all point sources, assuming maximum permitted flow: 65.0334 MGD (100.62 cfs)
- Total flow contribution from all point sources minus UOSA: 1.0334 MGD (1.60 cfs)
- Average daily natural flow in the Occoquan Watershed: 550 cfs
- Total average daily flow (natural + max. permitted): 650.62 cfs
- Non-UOSA permitted flows are 0.25% of this.
- UOSA is already represented in the Model with actual flows (not max.). All flows can be added at max. allowable, as necessary.


Linkage of Submodels
HSPF
HSPF
HSPF
CE-QUAL-W2
HSPF
HSPF
CE-QUAL-W2
HSPF
HSPF
Major Streams
Major Waterbodies
Watershed Segments
Bull Run Subbasin
Cedar Run Subbasin
Lower Broad Run Subbasin
Middle Broad Run Subbasin
Upper Broad Run Subbasin
Lower Occoquan Subbasin
N
W
E
S
0 5 10 Kilometers



Branch 2
(Bull Run)
Monitoring Stations
Occoquan Reservoir
0
1.5
3 Kilometers
RE30
RE35
RE15
Branch 3
(Sandy Run)
Ryan's Dam
Branch 1
(Occoquan River)
RE02
N
W
E
S
Branch 4
(Hooes Run)

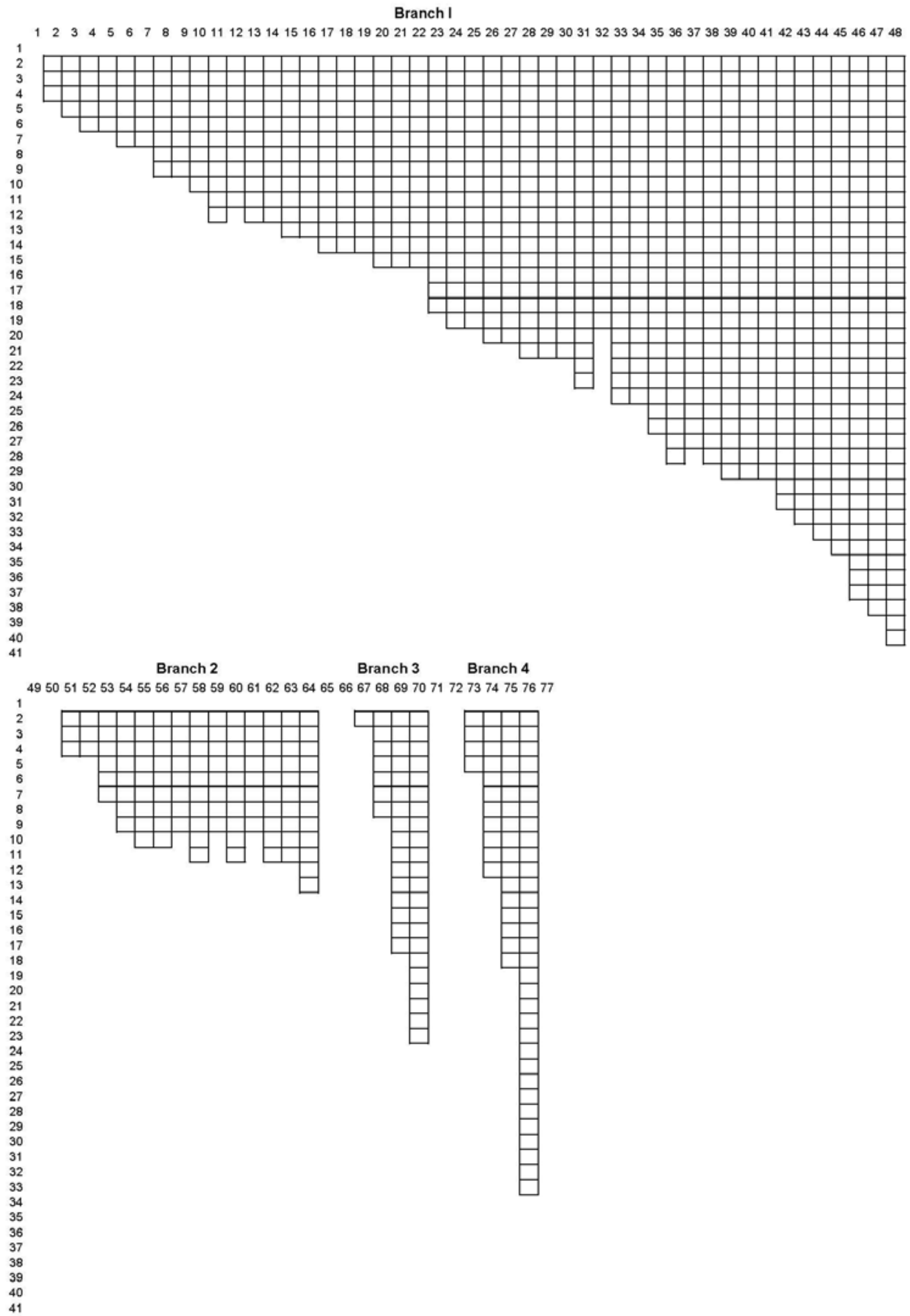
Schematic of Occoquan Reservoir Segments in CE-QUAL-W2 Model



Occoquan Reservoir Model Schematic Showing Layers in Each Branch (Branch 1 = Occoquan River and Reservoir downstream of Lake Jackson)

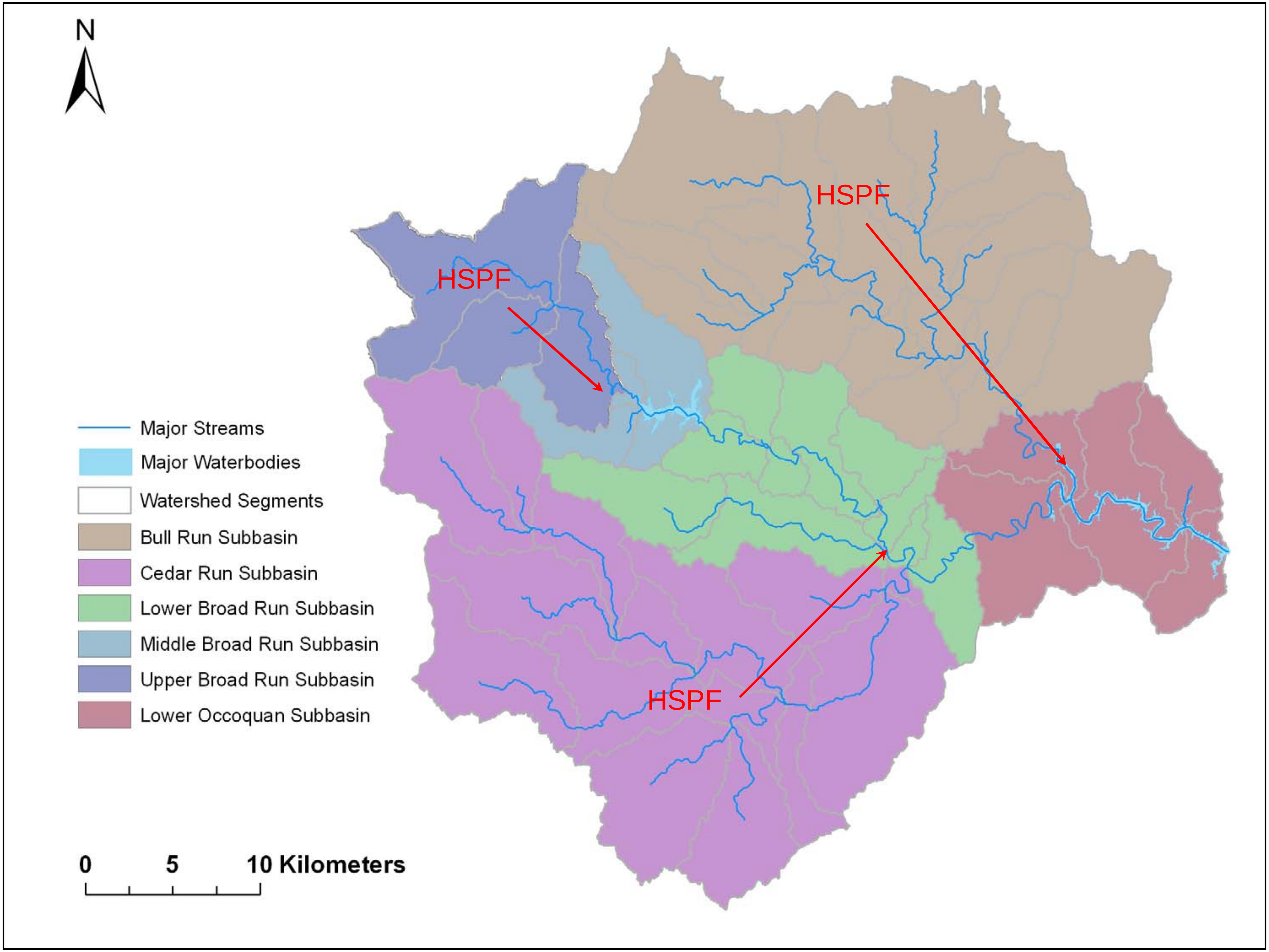
Each Layer is 0.5 m deep

Not To Scale



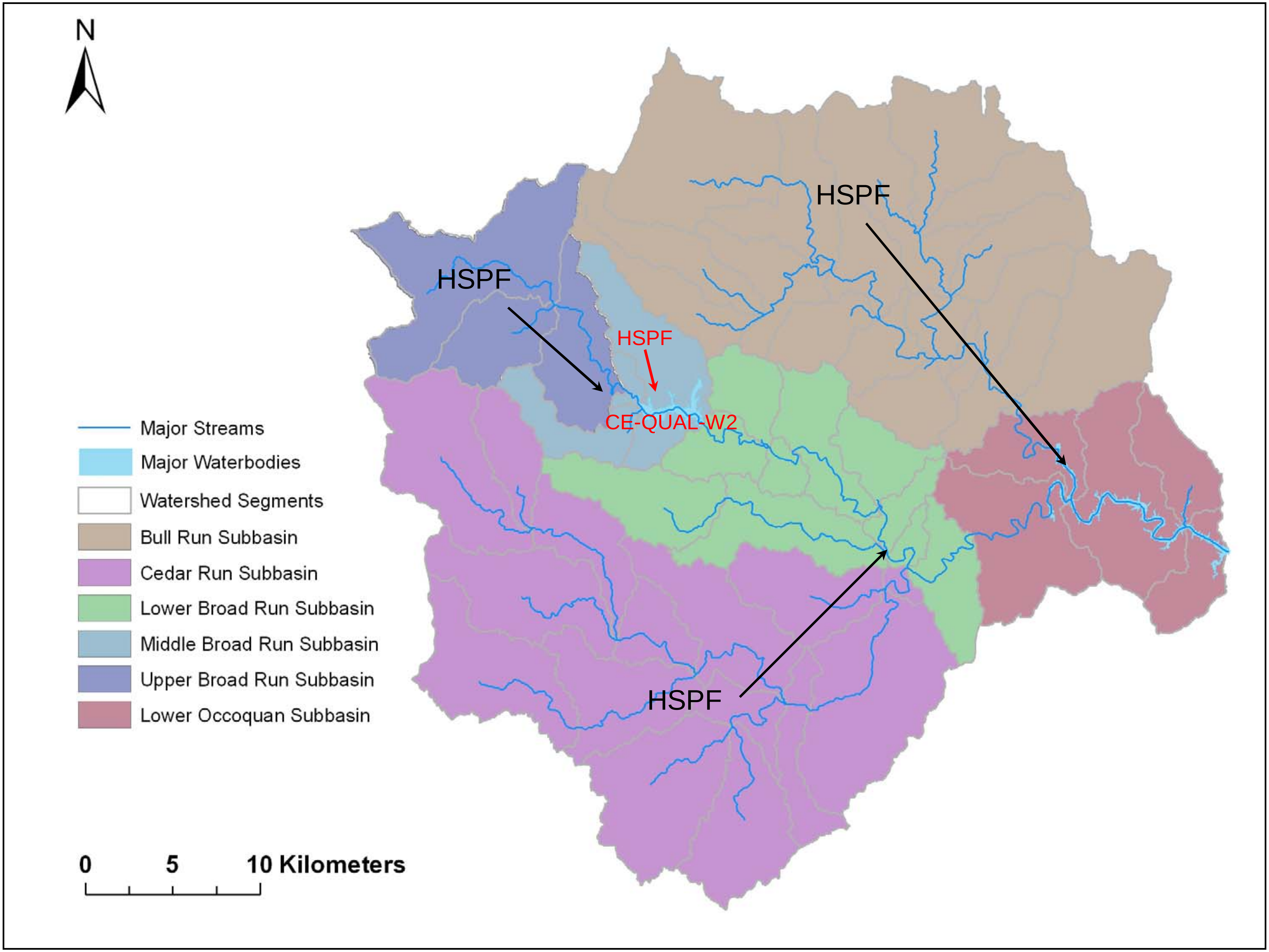
Modeling Process - I

- Start with the most upstream HSPF models (Upper Broad Run; Cedar Run; Bull Run).
- Calibrate these to stream monitoring stations at mouths of subwatersheds.


N
HSPF
HSPF
HSPF
Major Streams
Major Waterbodies
Watershed Segments
Bull Run Subbasin
Cedar Run Subbasin
Lower Broad Run Subbasin
Middle Broad Run Subbasin
Upper Broad Run Subbasin
Lower Occoquan Subbasin
0
5
10 Kilometers

Modeling Process - II

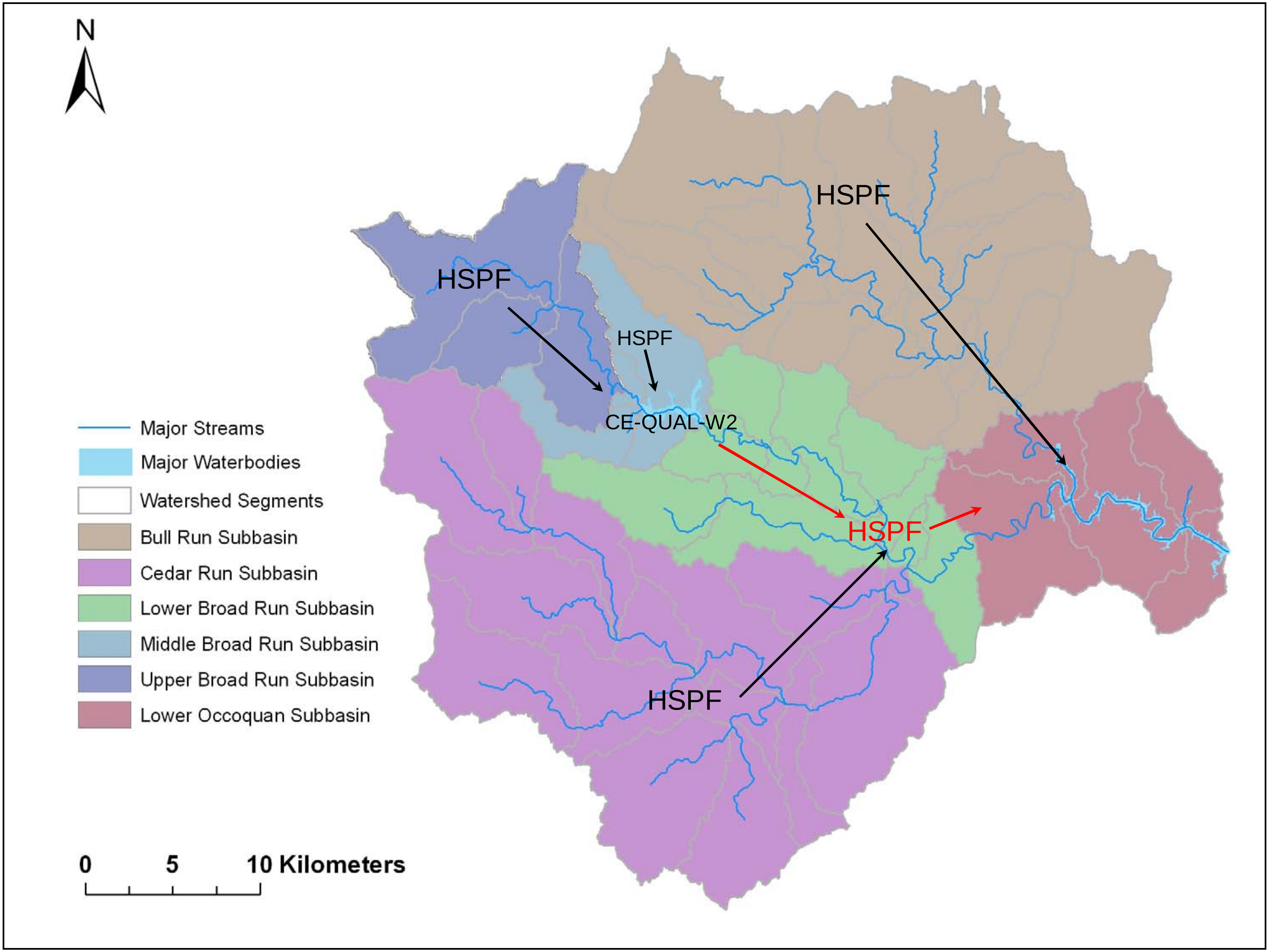
- Use calibrated output from Upper Broad Run and output from Middle Broad Run submodels at input to Lake Manassas CE-QUAL-W2 submodel.
- Calibrate to in-Lake stations.



N
HSPF
HSPF
HSPF
CE-QUAL-W2
HSPF
Major Streams
Major Waterbodies
Watershed Segments
Bull Run Subbasin
Cedar Run Subbasin
Lower Broad Run Subbasin
Middle Broad Run Subbasin
Upper Broad Run Subbasin
Lower Occoquan Subbasin
0 5 10 Kilometers

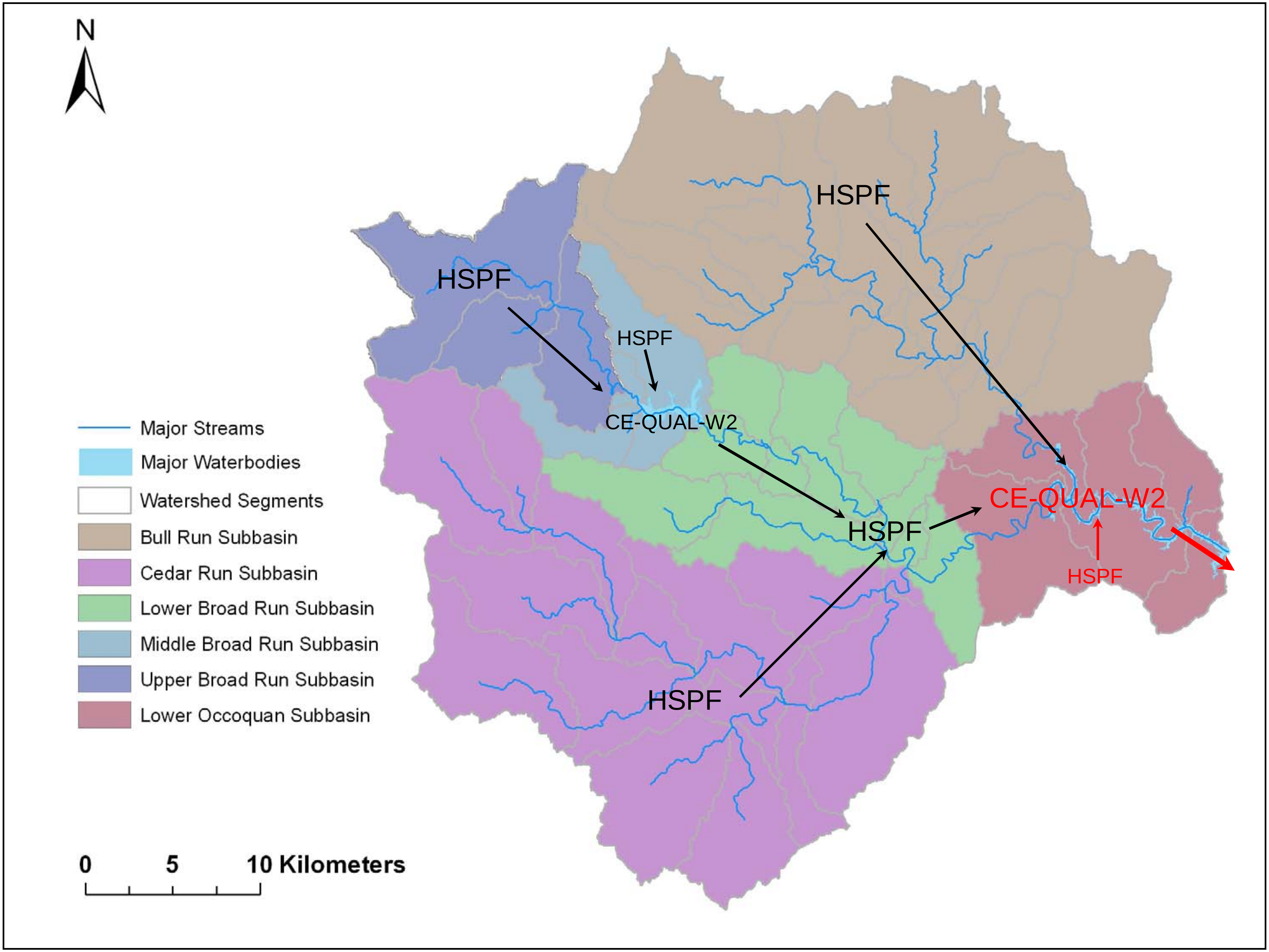
Modeling Process - III

- Use calibrated output from Lake Manassas CE-QUAL-W2 submodel and Cedar Run HSPF submodel as input to Lower Broad Run HSPF submodel.
- Calibrate this to downstream station.


N
HSPF
HSPF
HSPF
CE-QUAL-W2
HSPF
HSPF
Major Streams
Major Waterbodies
Watershed Segments
Bull Run Subbasin
Cedar Run Subbasin
Lower Broad Run Subbasin
Middle Broad Run Subbasin
Upper Broad Run Subbasin
Lower Occoquan Subbasin
0
5
10 Kilometers

Modeling Process - IV

- Use calibrated output from Lower Broad Run and Bull Run submodels, and output from Lower Occoquan HSPF submodel as input for Occoquan Reservoir CE-QUAL-W2 submodel.
- Calibrate this to in-Reservoir stations.
- Finally, go back and fine-tune the entire calibration, repeating the process as needed.

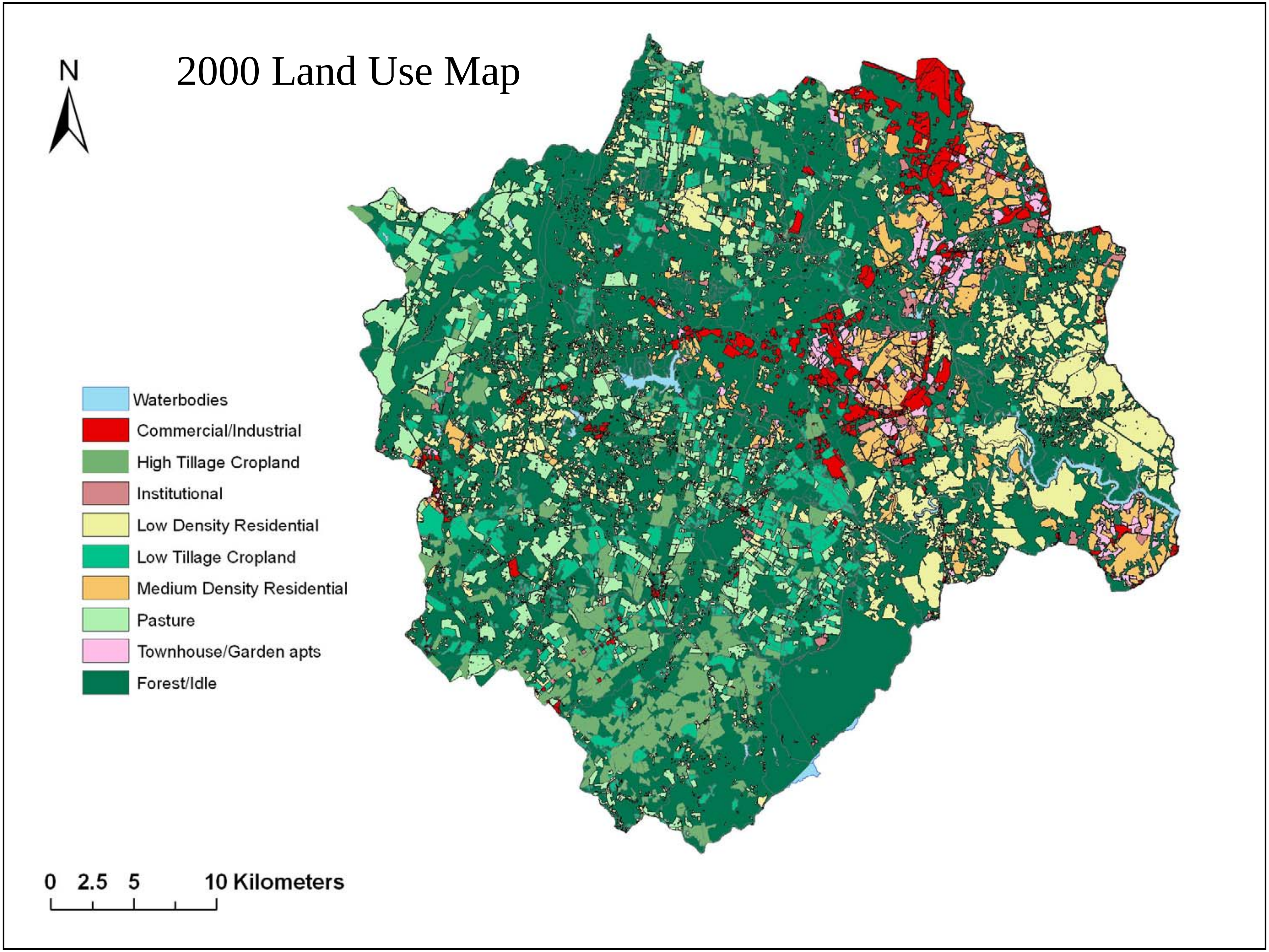

N
HSPF
HSPF
HSPF
CE-QUAL-W2
HSPF
CE-QUAL-W2
HSPF
HSPF
Major Streams
Major Waterbodies
Watershed Segments
Bull Run Subbasin
Cedar Run Subbasin
Lower Broad Run Subbasin
Middle Broad Run Subbasin
Upper Broad Run Subbasin
Lower Occoquan Subbasin
0 5 10 Kilometers

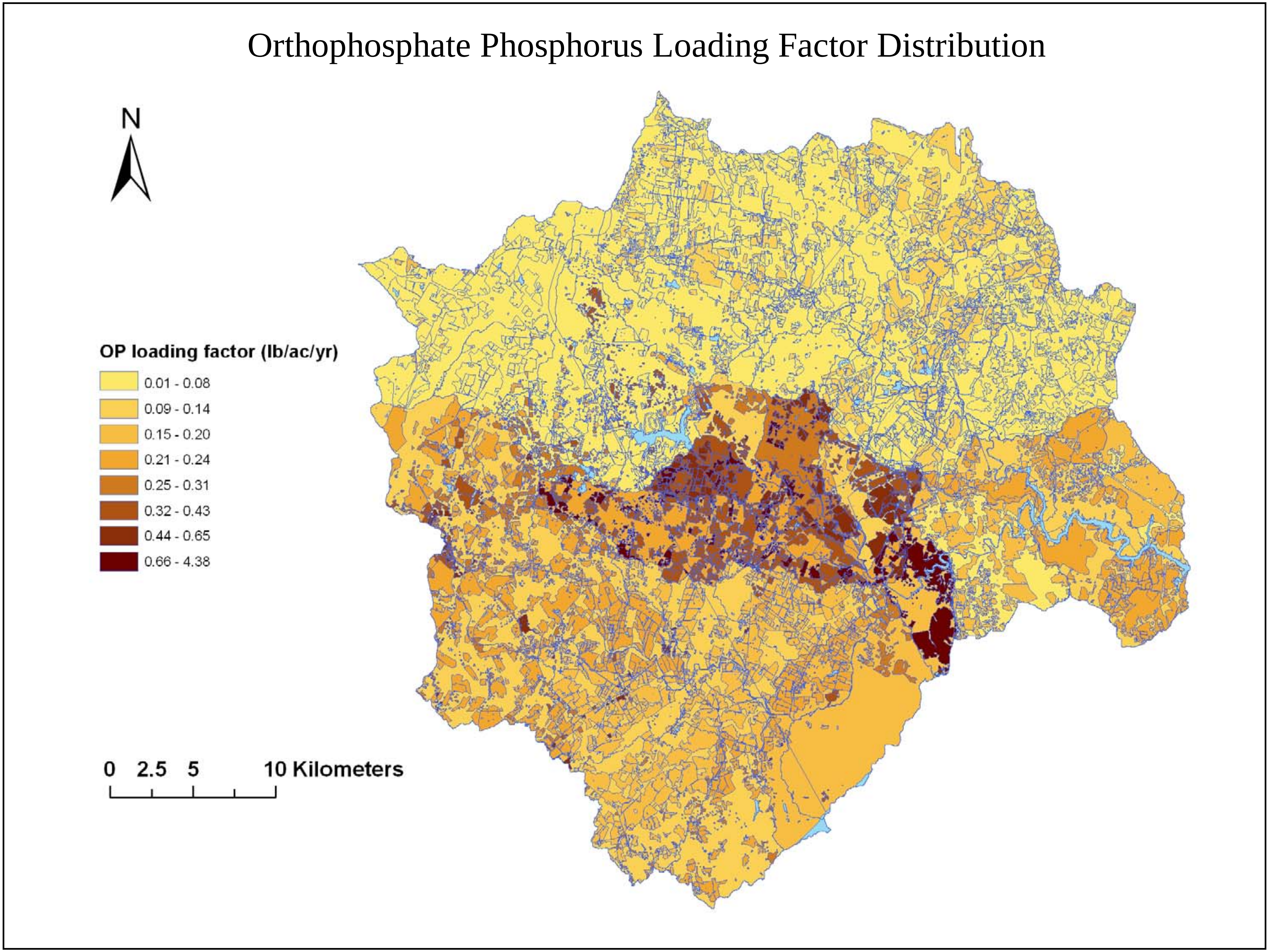
Model Calibration Goals

- Typically, watershed (HSPF) models are calibrated for loads (monthly, annual); and reservoir (CE-QUAL-W2) models are calibrated for concentrations (instantaneous).
- All submodels of the Occoquan Model were calibrated for both, loads and concentrations.
- This resulted in some compromises, but the goal was to balance both types of methods to obtain a model that would be useful across a wide range of applications.

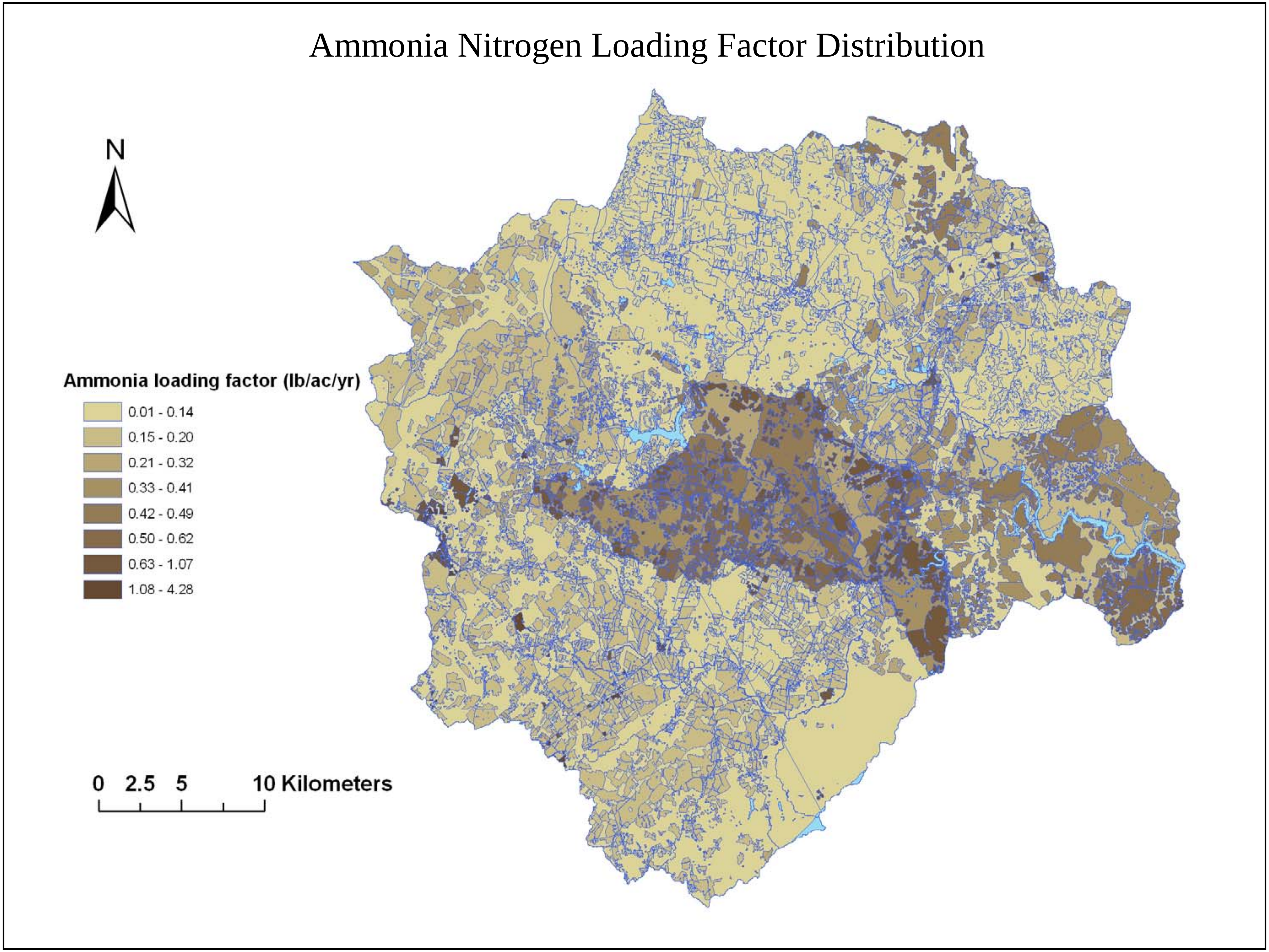
How Will the Model Be Used in Developing any TMDL?

- HSPF has ‘loading factors’ associated with each land use type.
- Point discharges also have their loads represented.
- These can be adjusted for changes in land use, changes in BMP implementation, or changes in point loads.
- Any type of change on the land (land use, point discharge, etc.) will then result in changed output from the HSPF submodels.
- The output from the HSPF submodels will be routed to the Occoquan Reservoir submodel and the results examined to determine if TMDL goals are met.

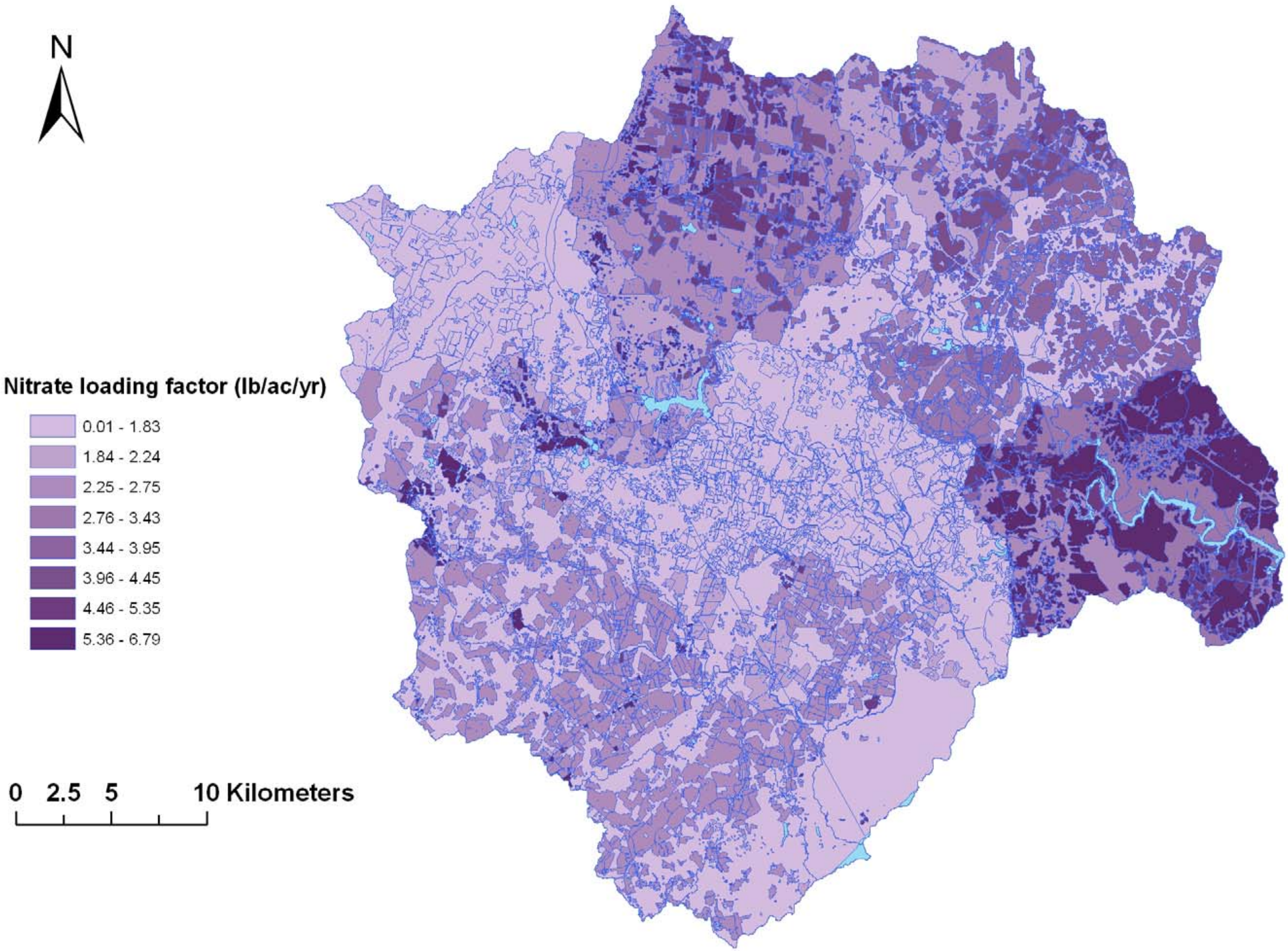

2000 Land Use Map
N
Waterbodies
Commercial/Industrial
High Tillage Cropland
Institutional
Low Density Residential
Low Tillage Cropland
Medium Density Residential
Pasture
Townhouse/Garden apts
Forest/Idle
0 2.5 5 10 Kilometers



Orthophosphate Phosphorus Loading Factor Distribution
N
OP loading factor (lb/ac/yr)
0.01 - 0.08
0.09 - 0.14
0.15 - 0.20
0.21 - 0.24
0.25 - 0.31
0.32 - 0.43
0.44 - 0.65
0.66 - 4.38
0 2.5 5 10 Kilometers


Ammonia Nitrogen Loading Factor Distribution
N
Ammonia loading factor (lb/ac/yr)
0.01 - 0.14
0.15 - 0.20
0.21 - 0.32
0.33 - 0.41
0.42 - 0.49
0.50 - 0.62
0.63 - 1.07
1.08 - 4.28
0 2.5 5 10 Kilometers

Nitrate Nitrogen Loading Factor Distribution



Other Considerations - I

- The Occoquan Model for 1998-2001, which utilizes the landuse data from 2000, will be used.
  - Landuse data for 2005-06 will not be available until 2007 at the earliest, at which point the Model update will take another 6-8 months. This will make it infeasible to use that update.
- The TMDL determination process will focus on the April-October period.
  - The Model will be run for the entire interval, but only the April-October output will be analyzed for the TMDL.

Other Considerations - II

- Fairfax Water has recently installed 8 SolarBee® (www.solarbee.com) systems upstream of the Occoquan Dam to provide oxygenation of deeper waters. Early data show that these are successfully increasing the DO in a deeper surface layer.


DANGER
KEEP OUT

Other Considerations - III

- The TMDL endpoint will likely be based on the proposed *Surface Water Standards*, which have separate criteria for lakes and reservoirs, and specific limits for the Occoquan Reservoir.

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